

# **Particle Size, Bed Properties, and Transport of Sediment on European Epicontinental Shelves**

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## **LONG-TERM GOALS**

The long-term goal of our research program is to advance scientific understanding and predictive modeling of sediment-transport processes in coastal and estuarine environments. The processes are important to the Navy because they define the tactical environment in shallow water and directly affect optical and acoustic properties of the water column. The resulting seabed structure and morphology affect acoustic backscatter and ability to locate objects on or near the bottom. Predictive capabilities for coastal sedimentary processes are also of great interest to geologists, coastal resource managers, and environmental scientists interested in mitigating coastal hazards, protecting or restoring coastal resources, or remediating contaminated marine environments.

## **OBJECTIVES**

We have been funded to participate in two ongoing ONR projects: EuroSTRATAFORM and OASIS. Our long-term research goals are closely aligned with the objectives of these programs.

EuroSTRATAFORM is a coordinated research program to measure and model the oceanic and geologic processes that erode, transport, and deposit sediment on continental margins, focused particularly on those events that form and destroy beds over time scales ranging from weeks to years. The broad objective of EuroSTRATAFORM is to transfer knowledge accumulated in the ONR STRATAFORM program, incorporate the expertise and insight of European investigators, and test our developing understanding of depositional marine systems in a different environmental context. Our scientific objectives under EuroSTRATAFORM are to improve quantitative models describing the relationships among meteorological and oceanographic forcing, freshwater and sediment supply, particle dynamics, bed properties, and transport and accumulation of sediment in the coastal ocean. The objective of our modeling work this fiscal year has been to continue to improve the Regional

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Ocean Modeling System (ROMS) simulations of the Adriatic Sea, and to evaluate the model using EuroSTRATAFORM field data.

OASIS (Optics acoustics and stress in situ) is a project funded by ONR to evaluate our understanding of suspended particle dynamics and its role in determining optical and acoustical characteristics of the water column. Field measurements will be used to evaluate a state-of-the-art model of particle dynamics and will lead to model improvements and enhanced ability to predict and interpret the optical and acoustical signature of sediments suspended by bottom stresses. The USGS participated in an OASIS experiment performed in September 2005, with the objectives of providing supporting field measurements and testing the sediment microscope camera system (“poking eyeball”).

## **APPROACH**

Our approach in both projects is to combine field observations with numerical modeling to a) improve model performance and b) use the models to interpolate and extend our insight beyond the limited field measurements. We are analyzing our data to determine velocity profiles, wave conditions, bottom stress, bottom roughness, suspended-sediment concentrations, particle characteristics, and sediment fluxes. We have built software for analysing data from newer instruments, including the Sontek pulse-coherent Acoustic doppler profiler (PCADP), the Aquatec acoustic backscatter sensor (ABS), and the Imagenex sonars. We now have programs to convert these data from their initial proprietary data formats to generic netCDF files and to perform quality checks and editing. We are also developing advanced techniques for analyzing bottom-boundary layer measurements that will provide us insight into sediment-transport mechanics. The software and processed data will be distributed to the public; analyses of the data will be reported in the scientific literature.

We have taken a community approach to developing the model, and are working with scientists and software engineers to improve the Regional Ocean Modeling System (ROMS). We have used the Adriatic Sea as one of our early test-beds for improvements in ROMS, especially in sediment-transport components.

Our approach to improving observational capabilities has centered on in situ measurements of bottom grain size with the poking eyeball. We had three goals for the poking eyeball in FY05: (1) modify the chlorine injection system that was designed to keep the optical window clean of biofouling, (2) test operation of the modified system at sea, and (3) deploy the instrument and collect data in cooperation with the OASIS experiment at MVCO.

## **WORK COMPLETED**

### **EuroSTRATAFORM: Analysis and Modeling of Adriatic Sea Data from the Po and Apennine Sediment Transport and Accumulation (PASTA) Experiment**

We have made significant progress in analyses of the PASTA field measurements. Current meter data have been processed and posted on our web site, near-bottom measurements have been processed and used to estimate sediment fluxes, and the sonar data has been quantified and compared against wave data and ripple models. These data are being incorporated into several scientific papers that are in preparation.

Detailed evaluation of forcing, bed response, and particle dynamics during transport events recorded at the Chienti tripods has continued in collaboration with other EuroSTRATAFORM scientists.

We have made significant progress in developing a community model for circulation and sediment-transport model, coupling this model with meteorological and wave models, and simulating sediment dynamics in the Adriatic Sea. A review of collaborative modeling efforts has been published (Sherwood et al., 2004) and several scientific papers are in preparation.

### **EuroSTRATAFORM: Gulf of Lions**

The USGS continued to provide significant logistical support to the EuroSTRATAFORM Gulf of Lions field program. USGS equipment (one ADCP and two guard buoys) were successfully deployed during the program, and USGS personnel participated on all three Gulf of Lions cruises, providing technical assistance to all participants. In particular, USGS technician Joanne Ferreira traveled to Spain in advance of each deployment, assisted investigators at the Spanish Institute de Ciències del Mar with preparation of their instruments and moorings, and participated in the Gulf of Lions cruises.

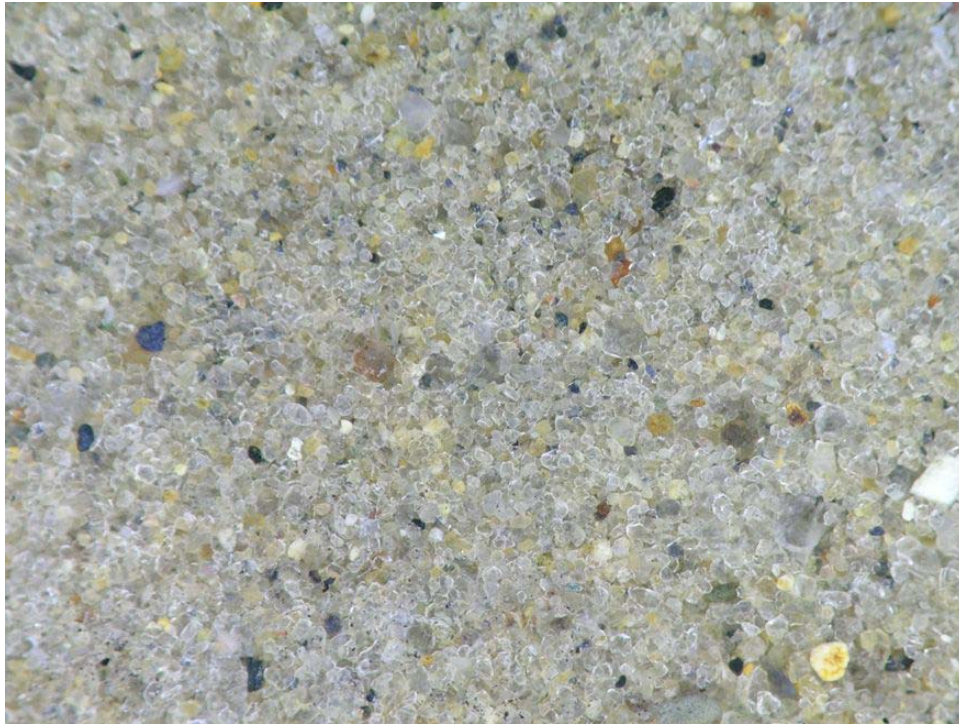
### **EuroSTRATAFORM and OASIS: Poking Eyeball**

The poking eyeball system originally slated for deployment in the Gulf of Lions was shipped back to California. The chlorine system was modified by rerouting the chlorine line and pump to avoid the electronics housing. The modified instrument (Fig. 1) was deployed off the Santa Cruz wharf for three days, where it worked flawlessly and collected 100 photos.



***Figure 1. Close-up view of poking eyeball after deployment at the Martha's Vineyard Coastal Observatory showing camera case, bottom-sensing switch, chlorine injection system, and window cover.***

The instrument was shipped to Massachusetts and deployed at the Martha's Vineyard Coastal Observatory (MVCO) in conjunction with the OASIS experiment, where it failed after taking three photos (Figure 2). The mechanical system that seals the optical window jammed, which prevented the camera from completing the photograph cycle or beginning the next cycle.



**Figure 2.** *Poking eyeball photo of bottom sediment at MVCO during the OASIS experiment. Field of view is approximately 14 mm wide x 10 mm tall. Standard grain-size analysis of grab samples from the tripod site indicate well-sorted fine sand with a moment mean of 2.7 phi and standard deviation of 0.54 phi.*

### **OASIS: MVCO Experiment**

The USGS deployed two instrumented tripods at the Martha's Vineyard Coastal Observatory as part of the OASIS experiment. The tripods were deployed approximately 10-m apart on one of the hummocky fine sand deposits that separate patches of much coarser sand. Tripods were deployed from the *R/V Connecticut* on August 28, 2005 and recovered using the same vessel on September 23. The particle tripod supported the poking eyeball and collected the following additional data: velocity profiles and wave measurements from a 1200 KHz acoustic Doppler profiler; time series of particle concentrations and size distributions at ~1.2 meters above the bed (mab) from a laser in situ sediment size and transmissometer (LISST); and images and profiles of bottom topography from rotating and one-axis profiling sonars. The flow tripod provided time series of bottom pressure and current profiles near the bed from a pulse-coherent acoustic Doppler profiler; time series of velocity fluctuations near the bed from an acoustic Doppler velocimeter; time series of near-bed profiles of sediment concentrations from an acoustic backscatter sensor, and time series of optical backscatter, light transmission, temperature and salinity. In addition, bottom sediment and water-column sediment samples were obtained to aid in instrument calibration. These data will be contributed to the pool of OASIS experiment data, and used to relate changes in optical and acoustical response with suspended-sediment concentrations and bottom stresses.

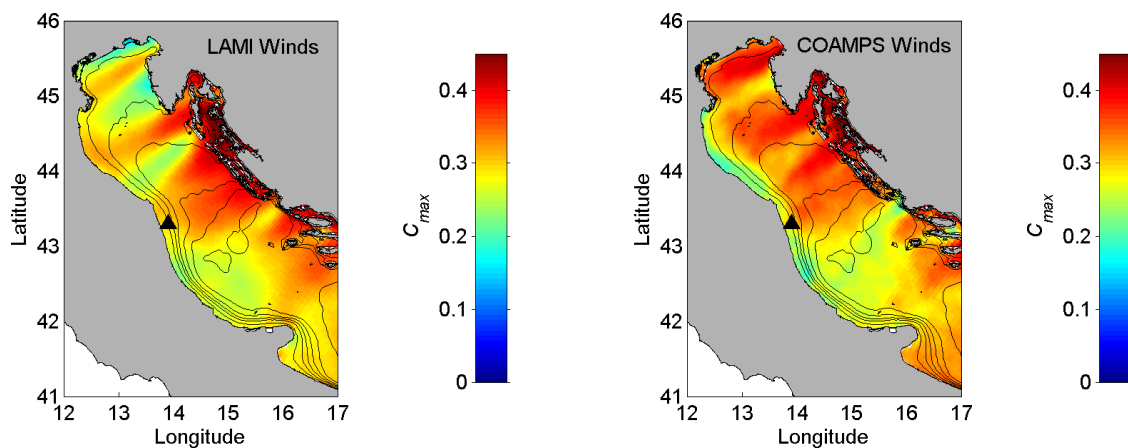


## RESULTS

EuroSTRATAFORM work in FY2003 resulted in a comprehensive set of data describing oceanographic conditions and sedimentary processes at the Chienti transect. Model results produced in FY2004 in collaboration with other EuroSTRATAFORM researchers provide us insight into the mechanisms that move Po River sediment hundreds of kilometers to depocenters north of the Gargano promontory. Model work in FY2005 has focused on developing a suite of model simulations using both LAMI and COAMPS winds, various bottom roughness parameterizations, and a range of initial bed sediment distributions. (The latter work was performed by Dr. C. K. Harris of VIMS with USGS input). We are now

The western Adriatic coastal current (WACC) is partially buoyancy driven, a forcing that increases during floods when suspended-sediment supply is highest. Observations and models demonstrate that Po water flows around the Gargano Promontory, but because the sediment aggregates and settles rapidly, it is unlikely that much remains in suspension for the entire journey. It appears that Po sediments must travel southward in a series of episodic transport events, and that wave-induced resuspension is important in these hops. Sediment-transport model results indicate that southward sediment flux is driven primarily by Bora events that generate large waves along the Italian coast and enhanced flow in the WACC. However, the model also indicates that Sirocco winds can generate large waves that resuspend sediment without reversing flow in the WACC, suggesting that southward transport can be forced by both Bora and Sirocco conditions.

Comparison of current measurements and wind models suggest that much of the forcing is remote. Local wind stress and bottom stress on the Chienti transect are only weakly coupled. Bottom stresses (and also flow and sediment flux) are better correlated with the large scale pattern of Bora winds in the central and northern Adriatic (Figure 3). This is evidence that wind-driven circulation in the northern Adriatic has a very large scale, and that waves are not necessarily collocated with Bora-enhanced southward flow.



**Figure 3. Maps of the maximum lagged correlation between measured bottom shear stress at the 20-m Chienti site (triangle) and modeled wind stress. Bottom stresses were estimated with the log-profile method between mid-November and mid-February, 2002-3. Wind fields from the LAMI model (left panel) were provided by Jacopo Chiggiato, ARPA Italia, and winds from the COAMPS model (right panel) were provided by James Doyle, NRL Monterey.**

Although research is ongoing to assess the skill of these models, results from the simulations are already helping us gain a better understanding of the mechanisms that form deposits on the margins of epicontinental seas.

## IMPACT/APPLICATIONS

The EuroSTRATAFORM data is being integrated with measurements of other PASTA researchers and those of other participants in Adriatic experiments last winter. Combined, this is one of the most detailed and comprehensive studies of circulation and sediment dynamics in a coastal sea. Analyses of these data, and their use in testing and improving models, is yielding new insights to coastal processes.

## PUBLICATIONS

Lee, C. M., Askari, F., Book, J., Carniel, S., Cushman-Roisin, B., Dorman, C., Doyle, J., Flament, P., Harris, C. K., Jones, B. H., Kuzmic, M., Martin, P., Ogston, A., Orlic, M., Perkins, H., Poulain, P.-M., Pullen, J., Russo, A., Sherwood, C., Signell, R. P., and Thaler Detweiler, D., 2005, Northern Adriatic response to a wintertime bora wind event: *EOS Transactions American Geophysical Union*, v. 86, no. 16, p. 157, 163, 165.

Sherwood, C. R., Book, J. W., Carniel, S., Cavaleri, L., Chiggiato, J., Das, H., Doyle, J. D., Harris, C. K., Niedoroda, A. W., Perkins, H., Poulain, P.-M., Pullen, J., Reed, C. W., Russo, A., Sclavo, M., Signell, R. P., Traykovski, P., and Warner, J. C., 2004, Sediment dynamics in the Adriatic Sea investigated with coupled models: *Oceanography*, v. 17, no. 4, p. 58-69.

## RELATED PROJECTS

**USGS Community Sediment-Transport Modeling Project** – USGS participation in EuroSTRATAFORM is closely linked with the community sediment-transport modeling project because the outstanding data set from Adriatic experiments in 2002-2003 provides an unparalleled opportunity to test and improve models of circulation and sediment transport. As noted in the Long-Term Goals section, the USGS and ONR have significant overlapping scientific interest in coastal ocean processes. The USGS has contributed salary and operating expenses to the PASTA and Gulf of Lions experiments and invested significant resources into the design and construction of the poking eyeball. The USGS will continue as a partner with ONR to help advance coastal ocean modeling capabilities.

**Instrumentation to Measure Bottom Roughness from GEOPROBE Tripods (Award Number: N0001401F0263)** – The USGS received ONR funding to develop the imaging/profiling sonar system. That project was completed in FY2002 with successful dockside testing of the new instrument. The new instrument was successfully deployed during the PASTA experiment, and obtained high-quality data (Figure 1). Plans and software for the system have been provided to other ONR investigators.

**Transport of Sediments and Strata Formation on the Adriatic Epicontinental Shelf (Award Number N0001402IP20011)** – The current project continues and expands research initiated with this project.



## **HONORS/AWARDS/PRIZES**

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